Lateral Epitaxial Overgrowth of GaN on Si(111)

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The lateral epitaxial overgrowth of GaN on Si(111) substrates was achieved using an extension of our standard LEO process on GaN/Al_2O_3 substrates, and the reduction of the dislocation density was demonstrated by transmission electron microscopy (TEM) and atomic force microscopy (AFM).

The growth on the Si(111) substrate was initiated with the deposition of a thin AlN buffer layer to avoid the formation of potentially detrimental silicon nitride at the interface. The wafers were then patterned with a SiO_2 layer in which 5 μm wide opening separated by 35 μm were etched using buffered HF. After reloading the samples in the MOCVD chamber, the LEO growth was performed using our standard parameters. There are a few unresolved issues concerning the effect of the AlN buffer thickness and its chemical compatibility with the SiO_2 mask layer, but after a basic optimization we were able to obtain ~5 μm of lateral overgrowth with smooth sidewalls in a reproducible manner (see Figure 1). We are currently investigating the use of mask materials other than SiO_2 to achieve LEO on Si(111) over a wider range of process parameters.

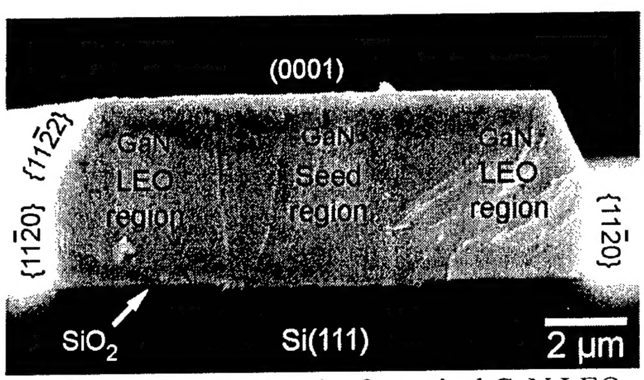

Figure 1 Cross section SEM micrograph of a typical GaN LEO <10$\bar{1}$0>-oriented stripe on Si(111) after 60 minutes of growth. Stripes as long as 300 μm were free of cracks, whereas wider stripes resulting from regrowth longer than 120 minutes showed cracking related to thermal expansion mismatch.

Figure 2 illustrates the striking reduction of the dislocation density in the LEO regions of the sample shown in Fig. 1. The residual dislocations in the LEO region are indicated by white arrows and are most likely related to the presence of the inclined facet. Although it is not clear at this point that these dislocations would have a detrimental effect on device performance, their formation can in principle be avoided by optimizing the LEO growth parameters to eliminate the inclined facet.

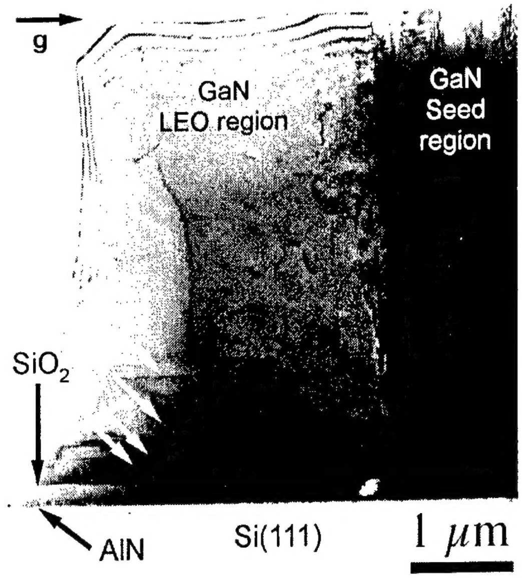

Figure 2 Cross section (bright field, g=11$\bar{2}$0) TEM micrograph of the sample shown in Fig. 1. The irregular top and side surfaces are due to ion milling.

Figure 3 shows the morphology of a typical LEO GaN stripe on Si(111) measured by AFM. The absence of step terminations in the LEO region clearly indicates that there are no screw-component threading dislocations in this region, which confirms the TEM observations on a larger surface area. The step configuration in the LEO region is related to crystallographic directions as we observed earlier.

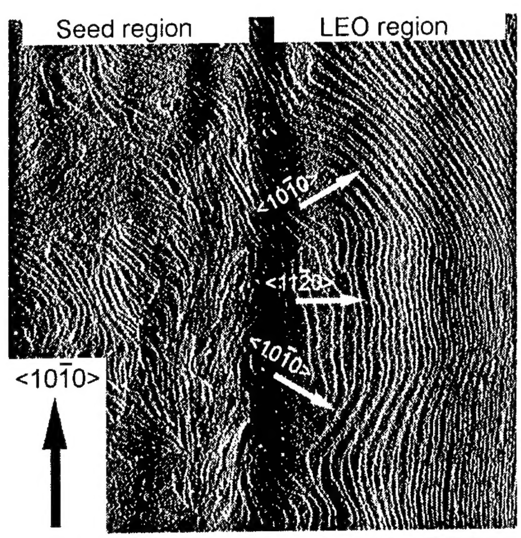

Figure 3 Surface topography of LEO GaN on Si(111) measured by AFM. The contrast in this image is related to the amplitude of the tip vibration during tapping mode imaging. The scan length is 4 μm.